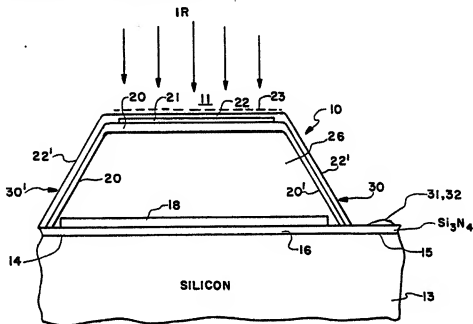




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(54) Title: MICROSTRUCTURE DESIGN FOR HIGH IR SENSITIVITY



(57) Abstract

A microstructure design for high IR sensitivity having a two level infrared bolometer microstructure, the lower level having a reflective metal film surface such as Pt, Au, or Al to reflect IR penetrating to that level, the upper level being separated from the lower level by an air gap of about 1-2 microns which allows the reflected IR to interfere with the incident IR and increase the sensitivity to a higher level.

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MICROSTRUCTURE DESIGN FOR HIGH IR SENSITIVITY

FIELD OF THE INVENTION

The field of the invention is in a high sensitivity two-level microstructure infrared bolometer array which can produce absorptance levels of greater than 80% and also achieve high IR sensitivity over a wavelength range from 8-14 microns.

BACKGROUND AND SUMMARY OF THE INVENTION

This invention is an improvement on co-pending application Serial Number 887,495, filed July 16, 1986, entitled "Thermal Sensor", and assigned to the same assignee as the present invention. The teachings of the co-pending application are incorporated herein by reference. In the co-pending application the invention is directed to a pixel size sensor of an array of sensors, for an infrared microbridge construction of high fill factor, made possible by placing the detector microbridge on a second plane above the silicon surface carrying the integrated components and bus lines. The improvement in the present invention is directed to a structure which increases the sensitivity.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 and 2 are front and top views of a microstructure design according to the invention.

Figure 3 is a graphical plot of overall absorptance vs. wavelength of the device over a selected wavelength including 8-14 microns.

Figure 4 shows graphically the transmittance, absorption and reflectance of the resistive layer.

Figure 5 shows graphically absorption vs. air gap thickness.

Figure 6 shows absorption of entire structure vs. metal absorber thickness.

Figure 7 shows measured optical properties of Si_3N_4 .

DESCRIPTION

A cross section view of the two-level microbridge bolometer pixel 10 is shown in Figure 1. The device 10 has two levels, an elevated microbridge detector level 11 and a lower level 12. The lower level has a flat surfaced semiconductor substrate 13, such as a single crystal silicon substrate. The surface 14 of the substrate has fabricated thereon conventional components of an integrated circuit 15 such as diodes, bus lines, connections and contact pads (not specifically shown), the fabrication following conventional silicon IC technology. The IC is coated with a protective layer of silicon nitride 16.

The elevated detector level 11 includes a silicon nitride layer 20, a thin film resistive layer 21, preferably a vanadium or titanium oxide (such as V_2O_5 , TiO_2 , VO_x), i.e. AB_x a silicon nitride layer 22 over the layers 20 and 21 and an IR absorber

coating 23 over the silicon nitride layer 22. The thin absorber coating (approximately 20A thick) may be of a nickel iron alloy, often called permalloy. Downwardly extending silicon nitride layers 20' and 22' deposited at the same time as layers 20 and 22 during the fabrication make up the sloping supports 30 for the elevated
5 detector level. The cavity or gap 26 (approximately 1-2 microns high) between the two levels is ambient atmosphere. During the fabrication process, however, the cavity 26 was originally filled with a previously deposited layer of easily dissolvable glass or other dissolvable material until the layers 20, 20', 22 and 22' were deposited. Some other easily dissolvable materials are quartz, polyimide and resist.
10 Subsequently in the process the glass was dissolved out to provide the thermal isolation cavity or air gap (i.e., the air gap actually may be in operation, a vacuum gap). In Figure 1 the horizontal dimension, as shown, is greatly foreshortened. That is, the height of Figure 1 is exaggerated in the drawing compared to the length in order to show the details of the invention.

15 Figure 2 is a top plan view of the elevated detector level 11. This drawing is made as though the overlying absorber coating 23 and the upper silicon nitride layer 22 are transparent so that the resistive thin film layer 21 can be shown. In one preferred embodiment the material for the resistive layer 21 is a vanadium oxide, preferably V_2O_3 . Vanadium oxides have very strong changes in resistance with temperature allowing high sensitivity microbolometer operation. It also has a
20 low reflectance to IR in the 8-14 micron range. In the preferred embodiment at this time the V_2O_3 is operated in its semiconductor phase. Its deposition is preferably by the process of ion beam sputter which permits the deposition of very thin layers such as 50-75nm. This material was thus selected for its low IR reflectance together with a relatively high temperature coefficient of resistance (TCR). The ends of the resistive paths 21a and 21b are continued down the slope area 30 embedded in 20' and 22' to make electrical contact with contact pads 31 and 32 on the lower level.

25 Figure 2 also shows nitride window cuts 35, 36 and 37 which are opened through the silicon nitride layers 20 and 22 to provide access to the phos-glass beneath for dissolving it from beneath the detector plane. The sloping supports may be of the necessary length to provide adequate support and thermal isolation for the upper level 11.
30

Although the description is basically in terms of individual detector pixels, the invention is directed for use to an x, y array assembly of adjoining pixels forming an imaging or mosaic detector array. Each pixel assembly may cover an area
35 about 50 microns on a side, as an example.

Referring again to Figure 1 a sequence of fabrication steps for the upper level is described. Following the deposition of the silicon nitride layer 16 in

fabricating the lower level 12, a thin film layer 18 of reflective material, such as a metal film like Pt or Au, is deposited. The construction of the upper level can then commence. The detectors presently being described are intended for use in the 8-14 micron IR wavelength. The reflective layer 18 is on the lower plane 12. The vertical distance between reflective layer 18 and upper level 11 is chosen so the reflected IR from layer 18 returned upwardly has interference properties such that significant absorption is achieved for a wide range of wavelengths (8-14 microns) and air gap spacing between the reflector and the detector structure.

A layer of phos-glass or other easily soluble material in the range of about 1-2 microns thick is deposited and the slopes 30 and 30' are thoroughly rounded to eliminate slope coverage problems. The upper level silicon nitride base layer 20 is then deposited, the resistive film 21 is deposited, connections down the slope to lower plane contact pads are made, and a silicon nitride passivation layer 22 covers the layers 21 and 20. A thin metal absorber coating 23 (about 15-40Å) is deposited on top of the upper level. The slots 35, 36 and 37, earlier mentioned are made and the phos-glass is dissolved from beneath the detector plane. As earlier described, by depositing Pt, Au or other reflecting thin film 18 on the substrate before the stack is formed, it is possible to reflect transmitted radiation reaching the reflecting film back to the absorber coating.

The optical properties of the total structure are achieved by careful selection of optical materials with the proper optical and electrical properties. The top film must reflect little radiation and generally transmit a significant percentage of the non-absorbed radiation through to the reflected light at a nodal position in the film determined by the air gap distance. An additional constraint on this absorbing film is that to be compatible with the total structure, the absorbing material must be very thin (and hence have a low mass).

To optimize the absorption in the structure, the thickness of all the absorbing layers and the air gap distance must be controlled. The absorbing films in the present device consist of ABx, SIN, and the thin absorbing metal described above. In practice, the ABx and SIN nitride thicknesses are chosen by electrical and physical requirements. Both have absorption levels ranging from 10-20% in the spectral region of interest (Figures 4 and 7). A combination of these materials produces an absorption of no more than about 30% in the 8-14 micron region. This absorption level is very close to ideal, however, for use with a Pt reflective layer and an air gap which intensifies the field in the absorbing film, it is possible to achieve absorptances in excess of 80% (Figure 3) in this configuration. The use of a thin absorbing metal which in the standard design provides 50% absorption, here is used to fine tune the

absorption for maximum effect. Figure 6 shows the small absorption improvements that can be achieved by using this metal film.

In this two-level structure, the low thermal mass structure 11 is separated from the Pt/substrate layer by an air gap. The interference properties of this reflected radiation are such that significant absorption is achieved for a wide range of wavelengths and air gap spacing between the Pt reflector and the detector structure.

For this optical interference to occur in the detector, it is necessary to avoid other films in the detector structure which reflect IR. The use of AB_x which has both a high TCR and a low IR reflectance (Figure 4) ideally meets these requirements. Thus the merging of this absorption phenomenon into a detector structure which has a detector material processing both a high TCR and low reflectance permits this interference effect to occur.

There is a substantial degree of variability of detector absorptance with air gap in the structure. Referring to the table below which shows wavelength in nanometers in the left column vs. air gap in microns across the top it can be seen that with an air gap of only .5 micron the detector absorptance varies widely with wavelength and is not very high. With air gaps of 1-2 microns and especially at 1.5 microns the absorptance is relatively high across the desired wavelength spread.

TABLE 1 - DETECTOR ABSORPTANCE

		Air Gap (Microns)				
Wavelength (NM)		.5	.75	1.0	1.5	2.0
25	8000	.89	.91	.9	.84	.76
	9000	.84	.88	.89	.86	.81
	10000	.76	.82	.84	.84	.82
	11000	.69	.77	.8	.82	.82
	12000	.66	.74	.79	.83	.84
30	13000	.64	.78	.85	.93	.94
	14000	.56	.72	.83	.95	.98
	15000	.47	.64	.77	.92	.99

The effect of gap thickness on the absorptance vs. wavelength in the regions of interest are further displayed graphically in Figure 5. It can be seen in the curve of 1.5 microns gap thickness that at 8 microns the absorptance of the structure is climbing rapidly towards 90% and more, and that it remains relatively high out to about 14 microns. The curve for a gap of 2 microns shows that at IR wavelengths of 14 microns the absorptance is better and well

above 90%. In measuring the data for Figure 5 the absorber film 23 was not included in the stack structure.

Referring now to Figure 6 there is shown graphically how the overall absorptance of the film structure varies across the IR wavelength of 8-14 microns as the thickness of the metal absorber film is increased to 3nm and 5nm. In this film stack design the Si_3N_4 layer 22 is 250nm, the resistive film 21 is 75nm and the Si_3N_4 film 20 is 100nm with an air gap of 1.5 microns and a reflective Pt layer 18 of 50nm. This curve for 3nm shows absorptance > 90% between 8 and 14 microns.

The measured optical properties of reflectance R, transmissivity T, and absorptance A of the silicon nitride layers 20 and 22 (800A thick) are shown in Figure 7 with percent of signal shown on the ordinate axis and IR wavelength along the abscissa. It can be seen that the transmissivity at 8 microns (about 90) and at 14 microns (about 80) is quite high and that the reflectance R at both 8 and 14 microns is well under ten.

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CLAIMS

The embodiments of the invention in which an exclusive property or right is claimed are defined as follows:

1. A two-level microbridge infrared bolometer structure
5 comprising:
 - a bolometer structure on a semiconductor substrate, said
structure having a lower section on the surface of the
substrate and a microbridge upper detector plane
10 structure spaced from and immediately above the lower
section;
an infrared-reflective thin film metal coating on the surface of
said lower section;
said upper microbridge detector plane structure comprising a
planar sandwich structure including a supporting
15 dielectric thin film layer, and a thin film temperature
responsive resistive element having first and second
terminals;
downwardly extending dielectric leg portion means which are a
downwardly extending continuation of said upper
20 structure dielectric supporting said upper microbridge
detector plane structure above said lower section so that
a thermal isolation gap exists between said upper and
lower sections; and
electrically conductive paths included in said downwardly
25 extending leg portion means connecting said first and
second terminals to said lower section.
2. The microbridge structure according to claim 1 wherein said
reflective thin film metal coating is selected from the group consisting of Au,
30 Pt, and Al.
3. The microbridge structure according to claim 1 wherein said
dielectric is of silicon nitride.
- 35 4. The microbridge structure according to claim 1 wherein said
thin film resistive element is selected from the group consisting of vanadium
oxide and titanium oxide.

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5. The microbridge structure according to claim 1 wherein said thin film resistive element is V_2O_3 .

5 6. The microbridge structure according to claim 1 wherein said gap between said lower section and said upper detector structure is in the range of about 1-2 microns.

10 7. The microbridge structure according to claim 2 wherein the coating is about 50nm in thickness.

8. The microbridge structure according to claim 1 and further comprising, in said planar sandwich structure, a second dielectric thin film layer and a thin film absorber layer.

15 9. The microbridge structure according to claim 3 wherein the first dielectric layer is on the order of 100nm in thickness and the second dielectric layer is on the order of 250nm in thickness.

20 10. The microbridge structure according to claim 8 wherein the resistive element film is on the order to 50-75nm in thickness.

11. The microbridge structure according to claim 8 wherein the absorber layer is on the order of 30nm in thickness.

25 12. A two-level microbridge infrared bolometer structure comprising:

30 a bolometer microstructure on a semiconductor substrate, said structure having a lower section on the surface of the substrate and a microbridge upper detector plane structure spaced from and immediately above the lower section;

an infrared thin film metal coating on the surface of said lower section, said metal being selected from the group consisting of Au, Pt and Al;

35 said upper microbridge detector plane structure comprising a planar sandwich structure including a first bridging dielectric thin film layer, a thin film temperature responsive resistive element selected from the group

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consisting of vanadium oxide and titanium oxide, said resistive element having first and second terminals, a second dielectric thin film layer over said first dielectric layer and resistive layer, and a thin film absorber layer;

5 downwardly extending dielectric leg portion means which are a downwardly extending continuation of said upper structure dielectric supporting said upper microbridge detector plane structure above said lower section so that an air gap on the order of 1-2 microns exists between

10 said upper and lower sections; and electrically conductive paths included in said downwardly extending leg portion means connecting said first and second terminals to said lower portion.

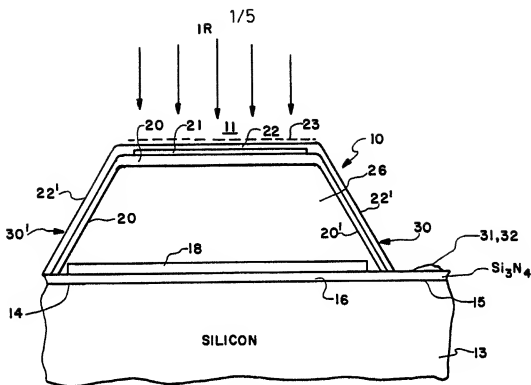


Fig. 1

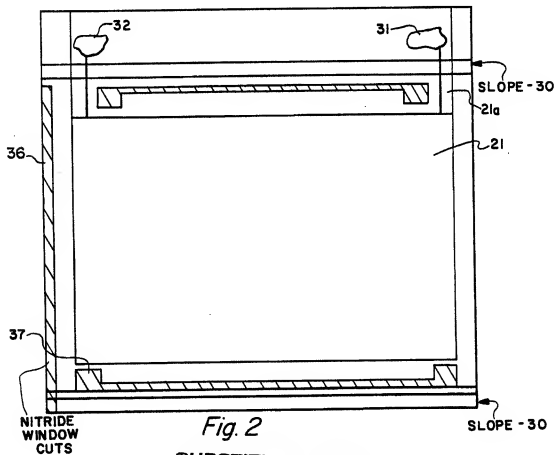


Fig. 2

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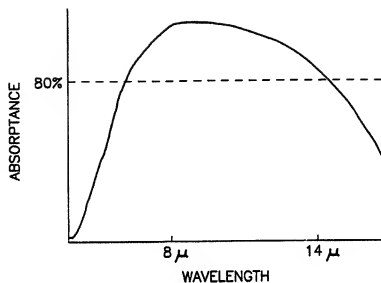


Fig. 3

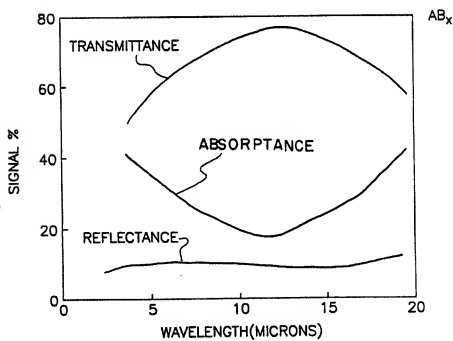
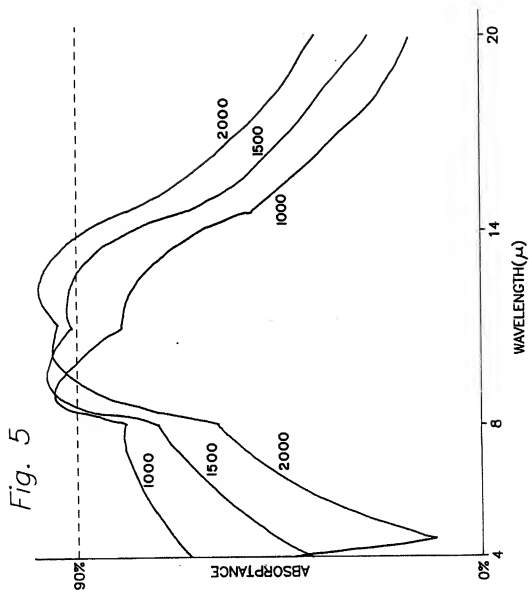


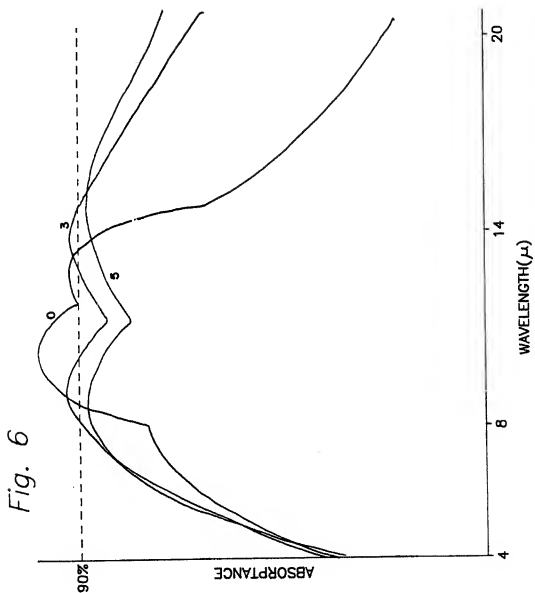
Fig. 4

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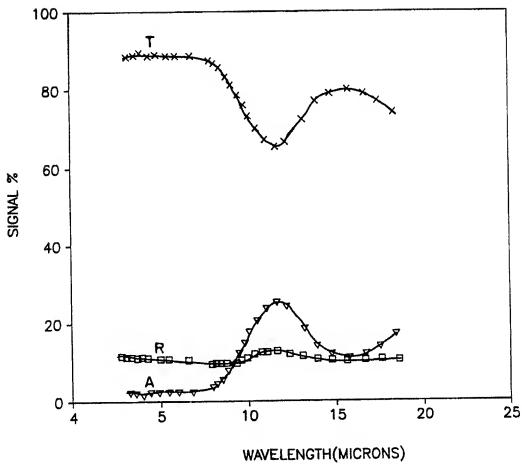


Fig. 7

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 92/05699

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to National Classification and IPC		
Int.C1. 5 G01J5/20		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
Int.C1. 5	G01J ; H01L	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages; ¹²	Relevant to Claim No. ¹³
Y	EP,A,0 354 369 (TEXAS INSTRUMENTS INCORPORATED) 14 February 1990 see the whole document	1,12
A	---	6
Y	EP,A,0 417 845 (PHILIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LIMITED) 20 March 1991 see column 8, line 19 - 1 : 38; claims; figures 3,7,12,13	1,12
A	---	1,3,8,12
	PATENT ABSTRACTS OF JAPAN vol. 16, no. 38 (E-1161)30 January 1992 & JP,A,32 48 477 (TERUMO CORP) 6 November 1991 see abstract	
	---	-/-
<p>¹⁰ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"B" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and out in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)	
Category *	Citation of Document, with indication, where appropriate, of the relevant passages
A	<p>PATENT ABSTRACTS OF JAPAN vol. 13, no. 387 (P-924)28 August 1989 & JP,A,11 36 035 (HAMAMATSU PHOTONICS) 29 May 1989 see abstract</p> <p>-----</p>
	1,3,8,12

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

US 9205699
SA 65269

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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EP-A-0417845	20-03-91	GB-A- 2236016 JP-A- 3146831 US-A- 5122666	20-03-91 21-06-91 16-06-92